Burn Rehabilitation and Research: Proceedings of a Consensus Summit

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Burn rehabilitation is an essential component of successful patient care. In May 2008, a group of burn rehabilitation clinicians met to discuss the status and future needs of burn rehabilitation. Fifteen topic areas pertinent to clinical burn rehabilitation were addressed. Consensus positions and suggested future research directions regarding the physical aspects of burn rehabilitation are shared. (J Burn Care Res 2009;30:543–573)

Advances in the medical and surgical management of patients who have sustained major burn injuries have resulted in unprecedented survival rates. This improvement has produced an ever increasing number of burn survivors with more complex rehabilitation needs. Burn survivors undergo physical and psychological recovery for months to years after a burn injury. Rehabilitation is a comprehensive process involving multiple team members working in collaboration to optimize a patient's recovery of their physical and psychosocial skills needed to return to their families, peers, and the community. However, for the purposes of this article, "rehabilitation" will hence forth refer to the physical recovery of patients with burn injury.

Many outcome studies report on the long-term psychological and social impact of burn injury. However, improvements in the physical rehabilitation of burn patients have occurred primarily on an institutional level. Questions regarding "best practice" and "standard of care" for physical rehabilitation evaluation and treatment remain unanswered. The practices of occupational therapy and physical therapy vary widely among institutions and few multicentered studies exist to evaluate the physical outcome of the burn survivor using sound scientific inquiry. Many burn clinicians agree that rehabilitation needs to advance on a path of established practice guidelines founded in clinical research. In response to this need, a consensus summit was organized.

In May 2008, a representative group of 20 clinicians with expertise in the physical rehabilitation of burn patients met in San Antonio, TX, to participate

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in a Burn Rehabilitation Summit (Summit). The purpose of the Summit was to discuss and debate, in an open forum, contemporary practice and future direction of physical burn rehabilitation management and research. The goals were to identify existing best practices, determine areas in need of additional inquiry, and develop a collaborative network for resource sharing. Summit participants were tasked to read preparatory burn rehabilitation literature with a focus on the physical aspects of burn rehabilitation that affect patient care.

Representatives from 16 different burn centers in the United States, Canada, and Australia were present. Participants averaged 17.7 years of burn rehabilitation experience and represented the disciplines of occupational therapy, physical therapy, and physical medicine. The Summit lasted 3 days during which 15 pre-identified topics were addressed. Subject topics were introduced and discussed in a general session followed by small breakout groups and concluded with a synopsis and rebuttal of the information. Topics were approached in a pragmatic but pointed manner instead of global overview. Topics were assigned to individual participants for literature reviews and summation of small-group discussion before being collated in this document. The information that follows and position statements of this document are derived from consensus among the Summit participants on current practice and future research priorities.

ADMINISTRATIVE ISSUES AND INITIATIVES

Standards for administration of burn centers have largely centered on medical and nursing aspects of care. Despite recognition of the importance of burn rehabilitation,[1,2] little information is published regarding the administration of these services.

Staffing Ratios and Acuity

No published staffing ratios for burn rehabilitation services exist nor are there any published acuity tools for burn rehabilitation. The American Burn Association (ABA) guidelines for the Operation of Burn Centers do not specify a particular patient to therapist ratio, only that there must be one full-time equivalent burn therapist (either an occupational or physical therapist) assigned to the burn center.[3] The guidelines additionally specify that staffing must be based on patient activity but do not specify ratios or acuity considerations.

Meaningful staffing ratios should take patient acuity into account beyond simple patient census. Determining rehabilitation acuity will not only help to determine staffing ratios but also help to determine appropriate utilization of therapy services. As patients with burn injuries progress through various stages of recovery, their rehabilitation needs change. For example, an intubated intensive care patient may require many hours of highly skilled nursing care. This same patient may require only a few hours of skilled rehabilitation for splinting, positioning, and range of motion (ROM). Several weeks or months later, when the patient is no longer intubated and the wounds are mostly closed, the patient will require less nursing care. At this time, the need for rehabilitation increases up to many hours a day because the patient requires intensive ROM, gait training, activities of daily living (ADL) retraining, and scar control measures. A schema for burn rehabilitation priority and patient involvement was introduced recently and endorsed by the assembled Summit participants (Figure 1).[4]

When designing a burn rehabilitation acuity tool, the factors to be considered are as follows: burn eti-

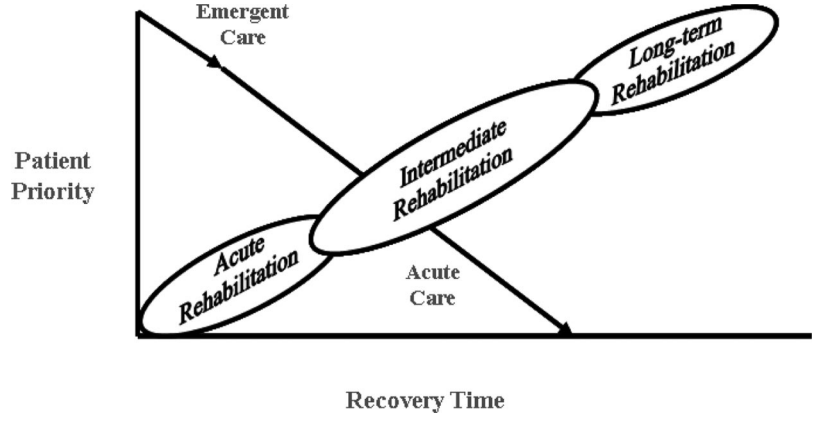

Figure 1. Phases of burn rehabilitation. Reproduced with permission from *J Burn Care Res* 2008;29:428.

ology, TBSA burn, phase of healing, age, time since burn, body areas involved, premorbid issues, amputations, neurologic involvement, need for interpreters, and comorbidities such as heterotrophic ossification, brain injury, blindness, and psychological factors. Issues of discharge support and location also add to the diversity of what can be considered rehabilitation.

Several models for burn acuity tools include the Patient Profile described by Cain et al[5] and the guidelines described by Bailes et al[6] and Kurtz.[7] Rehabilitation acuity tools specific to the burn population can be used to identify staffing requirements and to assist in educating payers about the need for individualized therapy services to meet the changing needs of the patients with burn injuries. An acuity scale needs to take into consideration the time and expertise needed for indirect care that is vital for successful rehabilitation and reintegration of a person with a burn injury.

Follow-up Clinic Staffing

Strong consensus exists that burn therapists are needed in an out-patient clinic to provide optimum care. However, there is no information to support or refute this position. Payment for therapy services is not sufficient for some centers to staff out-patient clinic therapists. In 2003, Kowalske et al[8] reported that 43% of patients with burn injuries had at least one contracture at discharge from the acute setting. This highlights a need for ongoing services after discharge.

Research shows a need for continued rehabilitation after discharge to increase muscle mass and maintain gains.[9,10] Quality of life is related to functional independence and hand function.[11,12] Children who have supervised exercise programs after hospitalization show a decreased need for surgical interventions.[13] Several authors have highlighted the need for continued services, but research is needed to demonstrate when rehabilitation services are most effective and how much therapy, both inpatient and outpatient, is needed to rehabilitate and integrate the patient back into society.[14,15]

New Therapist Competency/Orientation

The ABA guidelines for the Operation of Burn Centers specify that "There must be a competency-based burn therapy orientation program for all new therapists assigned to the burn center."[3] The guidelines do not specify what these competencies should be and burn centers have individually developed competencies. Guidelines for developing competencies have been published but no specific or unified competency criteria are published related to burn rehabilitation.[16]

Burn Certification

Burn therapists have advocated for a Certified Burn Therapist specialty designation. Such a certification could help insure proper training and expertise for the rehabilitation of patients with burn injury. Without competencies for burn rehabilitation care, it is difficult to define the clinical skills and knowledge base needed for this certification. If a Certified Burn Therapist program is designed, it could adapt a model similar to advanced burn life support, which includes a proficiency demonstration.[3] A certification process needs to be connected with an academic or professional organization with the credentials to support such a program.

Burn Rehabilitation Research Coordinators

Because of the need for an increased emphasis in the area of burn rehabilitation research, it is recommended that at least one therapist in each burn center be given time and responsibility to conduct rehabilitation research. Many burn centers have research nurse coordinators who write and submit grants, enroll patients, gather data, and monitor studies. Only a few burn centers have research therapists: Cornell Burn Center in New York, the United States Army Institute of Surgical Research in San Antonio, and Health Sciences Centre in Winnipeg, Canada.

Administrators should support dedicated time for burn therapists to perform research and to learn the grant process. Increasing the emphasis of research in burn rehabilitation will strengthen evidence-based practice, support insurance payment initiatives, and justify staffing. Ultimately, this will improve patient outcomes across the spectrum of burn care.

Summary

Burn rehabilitation is an important component in burn recovery, and there is a pressing need to administer and research these services in a more clinically relevant and cost-effective manner. Several topics of important relevance are listed in Table 1. Administrators of burn centers play a key role in this process and

Table 1. Burn rehabilitation administrative priorities

Develop and test a burn rehabilitation acuity system
Develop and test staffing ratios based on rehabilitation acuity
Advocate for increased payment for rehabilitation services in burn follow-up clinics
Develop standards of minimal competency for burn therapists
Explore development of a Certified Burn Therapist specialty
Provide and fund dedicated research therapists in the burn center

should support these recommendations to help advance the outcomes of burn survivors.

RESEARCH AND EDUCATION

With an increasing number of patients surviving larger burn injuries, there has been a greater emphasis on outcome studies.[17] Three main issues currently facing providers in burn rehabilitation pertaining to research include the following: 1) a failure to use a system to critically appraise existing burn literature relevant to practice among burn therapists, 2) the inability to systematically produce high levels of evidence that contributes new knowledge and practice patterns in all aspects of burn rehabilitation, and 3) the lack of a standardized knowledge base among therapists. All these issues require that a concerted effort be undertaken to alter current practice patterns and advance the production and consumption of high-quality scientific evidence related specifically to burn rehabilitation.

Research Background

The contributions of occupational and physical therapists to burn research are underdeveloped. The majority of studies related to rehabilitation overall focus on pain-related and psychosocial issues with a small percentage discussing physical rehabilitation or physical outcomes.[4] A literature review conducted by the authors in PubMed (http://www.ncbi.nlm.nih.gov/sites/entrez) using a date ranging from 1965 to 2008 and keywords burn, physical therapy, occupational therapy, physical rehabilitation, and physical outcomes generated only 29 randomized controlled trials that evaluated physical or occupational therapy-based treatments or physical outcomes. Esselman et al[18] performed an extensive literature review on the rehabilitation of patients with burn injuries. These authors reported that the majority of burn rehabilitation studies reviewed was of low scientific rigor and subject to considerable bias and lack of generalizability. They also reported that there was no strong evidence to support common interventions in burn rehabilitation.

Research Limitations

A number of obstacles to conducting research are present in any patient care setting, and the field of burn rehabilitation is of no exception. These limitations include limited personnel, time and financial resources, inexperienced burn therapists and clinical researchers, limited experience of clinicians in research and years of burn clinical practice, facility requirements that preclude staff continuity, and relatively small sample populations. To overcome these limitations and foster research in the burn rehabilitation community, it is recommended that larger burn rehabilitation facilities spearhead research initiatives. Additionally, facilities should conduct multicenter and international research collaborations and promote knowledge exchange. Collaborative research programs should be established between large and small facilities leveraging available technology to assist these efforts.[19,20] These collaborative efforts would allow pooling of personnel, patient populations, and other resources.

Not all burn centers will be able to independently conduct rehabilitation research. However, cooperation among burn centers could lead to an improvement in the quality of research and provide stronger evidence to support the interventions used in burn rehabilitation. The ABA Multicenter Trials Group provides resources to members to facilitate such activities because one of this group's missions is to promote outcomes of care for burn injuries through multicenter evidence-based research.[3]

The movement toward evidence-based practice has become pervasive throughout the healthcare and the medical community. This ideal entails incorporating the best available evidence, clinical expertise, and patient values into the management of patients. The practice of critically appraising and consuming the literature and incorporating it to improve patient care will also enhance a therapist's ability to communicate with physicians, justify treatments to insurance carriers, and fosters ideas for new research. Callas[21] reviewed commonly used study designs and discussed how to assess the quality of research studies. He makes a noteworthy statement in that "the reader needs a sound basis on which to judge the quality of each study, for in reality, all published research studies are not equally valid."[21] Thus, systematic reviews and internet-based sources of critical appraisals of burn survivor rehabilitation literature should be encouraged and actively supported by funding agencies. Research efforts should pool and leverage available resources to promote well-designed, randomized, controlled trials aimed at identifying the most efficacious treatment strategies and quantifying the risk of harm associated with these strategies.

Burn Rehabilitation Core Curriculum

Academic education programs for therapists provide only limited information about burn rehabilitation.[22] Therapists in burn centers responding to a survey in 2000 reported that they were minimally prepared for burn care in general.[23] However, burn therapists reported that they were best prepared for the specific in-

terventions by internships. This finding exposes the need for development of a core curriculum in burn education and for burn centers to provide therapy students with internship opportunities in burn rehabilitation.

Historically, introductory level programs for occupational and physical therapists have lacked education or means of critically evaluating the scientific literature. Although this deficiency is being corrected in current curricula, many practicing therapists still lack this important skill set. Both novice and experienced clinicians should seek to develop and hone these skills. Several avenues exist through continuing education, internet-based tutorials and reviews,[24,25] and existing texts.[26–28] Establishing an online education program for therapists with varying levels of skill and years of burn care experience would be an extremely useful tool. A program such as this may also benefit other members of the burn team by providing education regarding the therapist's role. Although a web-based program would have many benefits, readily available financial support for such endeavors is lacking.

Therapists should seek opportunities through professional organizations for educational advancement. Burn center verification guidelines stipulate that burn therapists must be provided with two opportunities per year of burn-related continuing education and that the primary therapist have 16 hours or more of burn-related education.[3] The ABA offers its members a number of programs to advance the educational and research needs of burn care professionals. The Education Exchange Program provides therapists with some financial support needed to acquire research training necessary for participating in and/or conducting research studies.[3] Furthermore, it is essential for therapists to become familiar with current research by reading journal articles, participating in regular journal clubs, and participating in online web programs or attending related conferences. These activities will enable therapists to interact with other professionals who can serve as mentors. When time and resources are not available, therapists may need to become their own advocate.

Summary

Rehabilitation interventions play a crucial role in the recovery of burn patients. It is incumbent on therapists to systematically investigate the efficacy of treatment in scientifically rigorous trials and publish their findings in peer-reviewed literature. Without multicenter prospective studies, methods of practice are based on each facility's techniques or philosophies that often lead to clinical controversies.[29]

In this article, broad topic areas pertaining to burn rehabilitation have been developed by consensus, knowledge gaps in the literature have been identified, and recommendations for future research were outlined. Results of these recommendations have the potential for far reaching impact on the outcome of patients with burns. One method of assessing this impact would be periodic literature reviews to identify new knowledge contributions in the scientific literature related to the topic discussed herein. Additionally, these recommendations could lead to high-quality outcome studies from which clinical practice guidelines can be developed.

DOCUMENTATION

Documentation is the standardized method by which clinicians record evaluations and treatments. It is extremely important to be detailed, exact, and descriptive for communicating to other practitioners, third-party payers, and reviewers. Occupational and physical therapists have standards for documentation set by their country's governing bodies: American Occupational Therapy Association, American Physical Therapy Association, Canadian Association of Occupational Therapy, Canadian Physiotherapy Association, Australian Association of Occupational Therapists, and Australian Physiotherapy Association.[30–35] Documentation in burn care must follow appropriate association standards and also include information particular to burn care.

Consistency in Terminology

Consistency in documentation and operational definitions and reliability in measures are imperative to successfully communicate between therapists and multiple burn centers and for data collection in research. For example, the following is a proposed operational definition of a burn scar contracture: an impairment caused by replacement of skin with pathologic scar tissue of insufficient extensibility and length resulting in a loss of motion or tissue alignment of an associated joint or anatomic structure. Contractures can affect a skin crease, skin juncture, or margin and may secondarily deform adjacent normal structures. Burn scar contractures are labeled according to the antithesis of movement impeded, resultant tissue deviation, or functional deformity (Table 2). Furthermore, recently published burn rehabilitation phases are endorsed as another example to facilitate uniform terminology.[4] Consistent terminology is necessary before uniform measures of scar, edema, and functional outcomes and other rehabilitation issues can be standardized.

Table 2. Burn scar contracture examples

Location	Limitation	Terminology
Antecubital crease	Elbow extension	Elbow flexion contracture
Posterior leg	Ankle dorsiflexion	Ankle plantarflexion contracture
Anterior axillary fold	Shoulder abduction	Shoulder adduction contracture
Lower lip	Normal alignment and mouth closure	Lip eversion contracture
Lower eyelid	Normal position and eye closure	Ectropion

Rehabilitation Data Collection

The ABA, in conjunction with the Trauma Registry of the American College of Surgeons (TRACS), established a National Burn Repository and burn registry software known as the National TRACS Burnware. Participating burn centers submit comprehensive data including patient injuries, treatment, and complications. Data specific to rehabilitation have not been part of the database in the past. A minimal set of rehabilitation data is recommended for inclusion in the burn repository (Table 3). Having a specific set of rehabilitation data included in the TRACS database would assist in data collection and research regarding physical outcomes of the burn patient and should be considered in future TRACS database enhancements. Additional web sites can be used for communication and information dissemination: www.burntherapist.com and www.repar.veille.qc.ca/burnengine.

Table 3. Minimal data set relevant to burn rehabilitation documentation should include the following

Etiology of burn injury
Body figure outline indicating depth of burn and location on body
Lund and Browder chart calculation of TBSA
Indication and location of escharotomy sites
Pain
Edema
Range of motion
Strength
Function
Sensation
Mobility
Positioning and splinting
Scar assessment
Scar treatment
Psychosocial skills and psychosocial components

Summary

Standardized and consistent documentation is imperative to successful communication. Documentation must meet discipline-specific standards, use uniform terminology, and contain a relevant minimal data set. Standardized documentation should be part of a universal database with qualified access, such as National TRACS Burnware. Such a resource would allow burn centers worldwide to communicate effectively and contribute to multicenter research. Recommendations are provided in Table 4.

HAND BURNS

Hand involvement as a part of an overall burn injury is common. Despite the fact that the surface area of the hand represents 1/40th of an individual's TBSA, an isolated hand burn is an indication alone for referral to a burn center for care. The hand ranks as one of the three most frequent sites of burn scar contracture deformity.[36–38] Because of the anatomic and functional complexity of the hand, topics concerning hand burns can be broad and varied ranging from edema control to outcome assessment and include wound management, splints, ROM exercise, positioning, and scar control. Despite the recognition that hand burns are problematic, this area of burn rehabilitation is no more advanced than any other anatomical area in terms of definitively improving patient outcomes. Overall, much clinical research is needed in the area of burn rehabilitation but this is especially true for hand burns.

There is a dearth of adequate literature that pertains to prognosis and outcomes after hand burns. The existing literature demonstrates a lack of appropriate description of factors such as anatomic location (eg, dorsal vs palmar injury), burn depth, tendon exposure, and concomitant injury after hand burns. Additionally, there is no consensus regarding treatment of hand burns across the spectrum of severity. The principle reason for this lack of consensus is the lack of well-controlled, rigorous comparative treatment studies. Despite the existence of several proposed algorithms for management of the burned hand, the

Table 4. Documentation recommendations

Use of consistent terminology
Development and acceptance of a minimum data set for burn rehabilitation
Development of a comprehensive burn rehabilitation data base
Increase utilization of current web sites for global communication

lack of validation studies in this area undermines their credibility and generalizability.[39–41] These knowledge gaps in the literature were dramatically illustrated by Esselman et al,[18] who reported a paucity of relevant hand literature pertaining to burn rehabilitation and the lack of randomized controlled trials in this area. Rigorous comparative trials for the treatment of hand burns and validated algorithms with embedded treatment protocols are recommended to facilitate clinical decision making for specific treatment approaches. When possible, burned hands are best treated by a therapist who specializes in burn rehabilitation.

Wound Management

The use of negative pressure dressings to treat burn wounds and to assist with skin graft adherence is a common treatment approach in burn care.[42] A problem created when using negative pressure therapy to treat hand burns is less than optimal position assumed by the fingers and thumb when the sponges are collapsed. Techniques need to be developed to adequately position the hand and fingers when negative pressure is applied. A burn therapist should be present when such a device is applied to insure appropriate hand and finger position.

The use of Kirschner wire fixation to immobilize fingers to protect exposed joints and tendons and for skin graft adherence is another commonly used technique.[43,44] However, absolute indications, ideal timing of pin placement and duration of use have yet to be defined. Furthermore, the rationale for the use of Kirschner wires in both pediatric and adult populations needs to be better delineated. In addition, optimal postoperative positioning or splinting of the hands and fingers in general needs to be identified, but especially when exposed tendons or open joints are involved.

Splint Practice

Many splints have been described to treat hand burns based on the customized need of each patient.[45] And, although the hand and fingers are the most frequently splinted site after a burn injury, efficacy of any type of hand splint remains in question.[46] Guidelines directing the use of splints related to the hand are based on burn depth, skin surface involved, burn rehabilitation phase, and patient considerations. No splint is needed to treat hand burns of superficial partial-thickness depth or if a patient is able to maintain full active ROM (AROM). Prophylactic antideformity splinting of the hand at night may be helpful to prevent contracture after deep partial-thickness and full-thickness burns. Splinting, or other means of positioning after skin grafting to the hands, is strongly recommended. A splint is highly recommended for patients who are unable to actively maintain their own ROM, who have a decreased level of consciousness, or who are deemed uncooperative with treatment. Controversy remains whether to splint a hand during the fluid resuscitation phase as discussed in later sections.

Range of Motion

Hand and finger ROM is a fundamental rehabilitation intervention after burn injury. Therapists use clinical judgment based on the appearance of the tissue as to whether passive ROM (PROM) or AROM is performed and also to determine when ROM is resumed after immobilization. The timing and indications to distinguish between immobilization, PROM, and AROM are preferentially decided by individual rehabilitation therapists. This variation in care is found throughout the rehabilitation phases. The optimal frequency, number of repetitions, and overall duration of stress application to scar tissue remain undefined.

Outcome Documentation

Many hand evaluations are available but no consensus has been reached on a battery of tests best suited to determine outcome of the burned hand.[18,47,48] A review of the literature and a survey is recommended to determine what information is currently available and being used. Subsequently, identified outcome measures will need to be tested for validity and reliability in the burn population.

The development of a minimal data set of patient information related to hand burns that is readily available and universally used is recommended. Within this data set, hand strength, ROM, dexterity, and sensory testing should be included. Although these evaluations are used in other hand injury populations, it has been difficult to assemble a functional outcome measure sensitive enough to use with hand burns. A burn hand evaluation including components relevant in each rehabilitation phase should be developed.

Summary

Hands and fingers are uniquely distinct because of their complex anatomy, functional importance, and frequency of being involved in a burn injury. Although hands are recognized as important structures, little research has been conducted relative to their importance. Tables 5 and 6 list topics of treatment consensus and research initiatives. Wound management with a rehabilitation perspective, optimal splinting, and ROM intervention, as well as a battery of

Table 5. Hand burn consensus topics

Superficial partial-thickness hand burns do not require splinting if full AROM is maintained
Apply a hand splint if the patient is unable to maintain ROM regardless of burn depth
Patients with deep partial-thickness dorsal hand burns should be allowed AROM during the day and splinted in at least 70° MCP flexion at night as long as tendon rupture is not of concern
No single hand test or battery of tests exists for functional hand assessment specific to the burn population
A burn therapist should be present when negative pressure treatment is applied to patients' hands

AROM indicates active range of motion; ROM, range of motion; MCP, metacarpophalangeal.

functional outcome tests to assess hand burn recovery, are essential areas for future investigation.

EXERCISE IN BURN PATIENT MANAGEMENT

Exercise is a fundamental part of a burn rehabilitation program. Therapeutic exercise encompasses ambulation, treatment of muscle and support structures, mobilization of joints, consideration of neurovascular integrity, improving cardiovascular and respiratory capacity, coordination, balance, muscle strength and endurance, exercise performance, and functional capacity.[49] However, types of exercise, the initiation of exercise, and the intensity and duration of exercise are areas requiring additional definition and exploration.

Exercise Concepts

The rehabilitation of patients with burns is a continuum of active therapy, and an exercise program is generally started at admission.[4,50] Exercise emphasis may be different in each phase of burn recovery and may require changes within a phase. A linear progression of exercise is not always applicable as medical status and surgical plans may warrant alterations in the performance, intensity, and duration of exercise. Exercise of patients with burn injury consists of two primary modes, ROM and conditioning exercises, which include functional activities. Initial emphasis is placed on preserving mobility and function and preventing loss of motion through positioning, splinting, and exercise. Increasing strength from a point of weakness and endurance toward patient "normal" (preinjury) and functional independence becomes essential as rehabilitation and restoration progresses.

Table 6. Future hand burn research direction

Critique available hand outcome measures for applicability to the burn population
Develop a hand burn functional outcome measure for both adult and pediatric patients
Determine benefits of hand splint use during burn resuscitation
Develop evidence-based hand burn algorithms
Study patient outcomes with finger pinning vs not pinning
Determine therapeutic dosage recommendations for range of motion and splinting of the hand

Exercise Dose-Response Relationship

An exercise regimen is prescriptive and should be administered according to an optimum dosage and frequency. Researchers have performed dose-response studies as it relates to muscle.[51,52] Currently, in burn rehabilitation, it is unknown how much exercise a patient needs to achieve an optimal outcome. Determination of appropriate exercise dose-response relationships in the burn population requires comparative controlled studies that account for age, location, and depth of burn wound associated with trauma, prior health status, individual metabolic response to injury, pain tolerance, and personal motivation.

Range of Motion Exercises

ROM is performed as active, active assisted, or passive exercise. A complete assessment of a patient's status determines the starting point for an exercise program. Clinicians should use the considerations listed in Table 7 to develop an individualized program.[53] Prolonged stress is thought to elongate scar tissue,[54] and applying a low load over a prolonged time is a commonly used approach; however, additional studies that measure the effects of low load, long-duration stress on burn scar tissue are needed. Parameters defining "functional ROM" need to be pursued, specifically as to how much ROM is required to perform various ADL and to maintain ROM.[55–62]

Table 7. Exercise principles

Based on biomechanical principles, slow sustained stress is more tolerable to the patient and more effective for producing tissue lengthening
Some exercise sessions should be done with the wounds exposed or pressure garments removed to observe tissue reaction
Observe blanching to avoid compromising vascularity for long periods
Elongate skin, scar, and muscle with combined joint movements
Choose functional exercises that will address ROM needs
Position limbs and joints after exercise to maintain increases in range of motion

Strengthening Exercise

Graded exercise programs include active exercises of moderate to high resistance and short-duration sessions aimed at strength maintenance and muscle hypertrophy.[50] Severe burn injury causes metabolic disturbances that can hamper rehabilitative efforts. To maintain body mass and synthesize amino acids into muscle protein, an exercise stimulus is needed.[63] A question to answer is whether a burn rehabilitation exercise protocol can mitigate the catabolic process when administered during the acute and intermediate phases of patient recovery.

A study of physical and psychological outcomes in young adult survivors burned as children showed that the majority of patients were within the normal range of function when compared with age mates without burns. Areas most likely to be impaired involved peripheral strength (wrist and grip) that affected some self-care skills.[64] In an adult population with burn injuries greater than 30% TBSA, significant weakness was found even years after the injury.[65] Additional longitudinal studies on the effect of exercise protocols on burn scar and muscle strength are warranted.

Aerobic Conditioning and Restoration of Function

Exercise intervention programs in adults and children have been effective in improving strength and function after injury.[9,10,13,66–69] Attempts to begin restoring aerobic capacity in critically ill patients may be the simple act of prolonged upright sitting and other out of bed activities.[70] Testing patients for changes in cardiopulmonary status in response to early mobilization are warranted. A recent investigation of aerobic capacity in deconditioned adult burn survivors showed improvement with a structured 12-week exercise program.[9]

Other studies have examined thermoregulation during exercise to determine the safety of exercise in burned children[71] and adults in extremes of heat.[72] Replication of these studies with various patient subsets and larger samples are needed to broadly apply these results.

Balance and Coordination Exercise

Except in patients with underlying balance and coordination or neuromuscular issues that may have factored into the cause of the burn, balance, and coordination are secondary problems that occur as a result of prolonged hospitalization, deconditioning, and loss of joint motion. These factors should be addressed as part of an overall exercise program.

Exercise Research

Research on the effect of exercise in burned adults is lacking. High-quality research in the pediatric burn population has shown exercise to be effective for increasing endurance and muscle strength,[69] increasing lean body mass and muscle strength,[10] increasing muscle strength and distance walked via moderate intensity, progressive resistive and aerobic exercise,[66] increasing pulmonary function,[68] and decreasing the need for burn scar contracture-related surgical interventions.[13] Additional research needed in the adult burn population is listed in Table 8.[9,67]

Summary

The benefits of exercise programs in restoration of function are well accepted; however, the optimal content of these programs is lacking. Basic exercise principles are presented in Table 5-1, but guidelines for standard burn exercise programs with defined exercise parameters and outcome measurements are needed. Multicenter trials and prospective studies to better define optimum exercise regimens are a priority for restoration of function.

BURN PATIENT PERIOPERATIVE REHABILITATION MANAGEMENT

The increased survival of patients with extensive burn injury has translated into the need for multiple excisions and skin grafting procedures. Increased burn size and the physiologic state of patients also have been associated with increased development of scar tissue contractures.[73] Multiple operative procedures and the medical state of the patient may result in extended periods of immobilization and thus lead to eventual suboptimal functional outcomes. Burn centers differ on immobilization time after surgery. Research is needed to determine the efficacy and risk of harm associated with early motion and mobility in the extensively burned patient.

Intraoperative ROM

The application of PROM under anesthesia has been described previously.[74,75] This evidence suggests that

Table 8. Exercise research priorities

Propose guidelines for exercising patients with burns specific to the phases of rehabilitation
Investigate devices that allow earlier exercise
Determine clinically broad based and useful tools for outcome measures
Evaluate dosage and frequency of exercise regimens in adult and pediatric patients with burns

ROM performed under anesthesia has several benefits. Intraoperative ROM seems to produce improved motion over preoperative testing.[74] Additionally, it provides an accurate baseline assessment of ROM limitations allowing more realistic treatment planning postoperatively. The practice of providing PROM and examination intraoperatively is supported, although additional research is warranted to delineate its therapeutic benefit.

Postoperative Positioning

Consistent agreement exists in the literature that positioning postoperatively is vital for optimal functional results[76]; however, controlled studies to document this supposition are lacking. One case series of axillary burns[77] offers some support to the conclusion that early splinting may help to prevent contractures as the rate of axillary contractures was lower than other reports in the literature.[73] However, such a comparison is tenuous at best because of differences in the postinjury evaluation times between studies and the lack of description of surgical intervention in the later report. Therefore, it is recommended that well-controlled prospective trials be undertaken to definitively establish the efficacy of this practice in anatomical locations of interest.

The application of thermoplastic orthoses intraoperatively to optimize postoperative positioning is widely practiced by burn therapists; however, there is little evidence supporting this practice. Clinical trials are needed to establish the efficacy of this treatment approach.

Postoperative Mobilization

The time between an operative procedure and postoperative mobilization varies amongst burn facilities but generally ranges between 4 and 7 days. There is limited evidence that skin graft adherence and wound healing were superior in children following rigid immobilization.[78] However, determining when and how much motion to permit is a clinical decision often based on graft location and appearance, principles of revascularization, patient compliance, and the grafts' immediate and next day response to movement. The optimal period of postoperative immobilization to establish graft adherence and minimize functional loss has not been established. Additional research in this area is warranted.

Early Ambulation

There is evidence to support implementation of early ambulation aftere lower extremity skin grafting.[79–83] Successful early ambulation has also been reported using splints[84,85] and plaster casts.[78] Superior graft adherence and fewer therapy sessions were reported in children when plaster casts were compared with posterior splints[78] but posterior splints seem to provide adequate support in adults.[84] Thus, substantial evidence exists in the literature to support early ambulation after uncomplicated lower-extremity grafting procedures with the support of an Unna's boot, plaster cast, or a posterior splint.

Summary

Operative procedures are an integral part of treatment for the vast majority of burn survivors admitted to the hospital. The immobilization period after these surgical procedures is commonly associated with loss in active and PROM. To counteract these negative consequences, interventions such as intraoperative ROM, postoperative positioning, and early postoperative mobilization have been proposed. Although early ambulation after uncomplicated lower extremity grafting procedures with external support has been well supported in the literature, all other interventions require additional investigation (Table 9).

SPLINTING AND CASTING

The application of splints is accepted as a treatment to oppose scar contraction forces that limit ROM and functional movement of the burn patient. Splint use has been described for all phases of burn care, from admission to after reconstructive surgery.[86–88] Indications for the use of splints in burn care include joint and skin graft protection, positioning to prevent deformity, and positioning to maintain or increase elongation of scar tissue.[89] The principles behind splinting are well established. However, the utilization of splinting is markedly varied among burn therapists, possibly because of the paucity of objective data regarding both intervention parameters and efficacy of splint use.[46]

Clinical Decision to Use a Splint

The decision to splint a patient may be influenced by rehabilitation goals or by burn center-specific philos-

Table 9. Perioperative rehabilitation management research priorities

Investigate short-term and long-term therapeutic benefits of intraoperative range of motion
Investigate benefits of postoperative and intraoperative positioning
Investigate optimal timing for postoperative mobilization out of bed
Investigate early postoperative mobilization of the extremities

ophies. Some burn centers advocate mobility in lieu of splinting and only use splints if AROM exercises or ADL are not maintained because of reasons such as noncompliance or severity of illness.[90] Other centers describe a more regular use of splints for immobilization and elongation of scar tissue.[91]

There is limited evidence comparing splinting to other treatment interventions. This is apparent in the treatment of the burned hand during the emergent phase of burn recovery. Some therapists elevate the hands and apply static splints to counteract the deforming hand position caused by edema.[92,93] Other therapists withhold splinting the hands in the emergent phase, instead elevating the upper extremity and encouraging active pump of the hand muscles to reduce edema.[90] An ideal ratio of time between mobilizing and immobilizing a patient has yet to be established through research, and the benefit of one approach over the other remains purely speculative.

To clarify the efficacy of splinting during the various stages of recovery after a burn, prospective, randomized controlled trials are needed that compare splinting with other interventions. One study compared the use of splints and casts to routine burn therapy and found that significantly fewer days were needed to correct burn scar contracture with splinting and casting.[94] Additional studies are needed to compare splinting with other treatment interventions and to determine the long-term benefits and short-term risk of the differing treatment approaches.

The decision to splint a patient with burn injury may also be based on which joints are involved. Limited evidence exists regarding the incidence of burn scar contracture development by anatomic location and it is unknown whether the risk of contracture is similar across all joint creases regardless of their location. In a cohort of 985 patients, Schneider et al[38] reported that the shoulder and the elbow comprised the majority of contractures (72%) followed by the wrist and the knee. Interestingly, a survey of burn therapists in the United States reported that the joints most commonly splinted were the hand/wrist complex, ankle, elbow, and axilla on admission following full thickness burn injury.[88] It is unclear why therapists are more inclined to splint some joint creases relative to others, particularly because the treatment objectives are assumed to be equal. Therapists' observation of different amounts of motion loss among joints may impact their clinical decision to splint one body part and not another. However, this treatment decision has not been objectively investigated and the rationale may lie instead with other considerations such as ease of fabrication, depth of burn injury, size of the body part, involvement of surrounding joints/skin, or a therapist's belief about the impact of splinting on functional mobility of the involved body part.

Timing of Splint Application. The timing of splint application during burn recovery and after surgical procedures is varied in practice and seems to have shifted over the last few decades. Historically, splints were used with patients immediately on hospital admission. However, more recent trends indicate that therapists may tend to delay splinting until a patient demonstrates decreased ROM.[86] Some literature describes splinting as a secondary intervention to be used when a patient is unable to voluntarily maintain proper positions or when positioning is ineffective.[93] The effect of early vs late splint use on functional return in the burn population is unknown and additional research in this area is required.

The decision to splint postoperatively seems to have shifted as well. Despite evidence that shows splints are safe to use over skin grafts, the use of postoperative splints has decreased following initial skin graft procedures and are used more commonly after reconstructive surgery.[87,95] Future research could help to determine whether splints are superior in preventing contractures when used after reconstructive surgery, acute skin grafting, or both.

Splint Design. There are no less than 134 splinting devices described in the literature and numerous additional devices described at each annual ABA conference.[96] Given the plentitude of options and the dearth of supportive literature, there is a lack of consensus among therapists for preferred designs to splint various joint skin creases. The actual device used to maintain limb position is typically of less importance than the limb position itself. Splints are seen as an extension of a positioning program to counteract ongoing scar formation and contraction of tissue,[93] so it would be beneficial to determine which splint designs most effectively place the limb in the optimal position. Despite the plethora of splint designs described, no comparative studies exist that evaluate the effectiveness of one splint over another for treating a defined problem. Therapists must begin to shift the focus of their efforts from describing splint design to investigating splint effectiveness through comparison studies. In addition to determining efficacy, splint studies should also compare material cost, ease of fabrication, patient compliance, and risk-to-benefit ratios.

Not only various splint designs should be compared but also splint types, because they all do not apply the same biomechanical principles. Three types of splints commonly described for use with the burn population are static splints, static progressive splints, and dynamic splints. Static splinting and static progressive splinting apply the biomechanical principle

of stress relaxation: the amount of force required to maintain tissue at a given length decreases with time. Dynamic splinting applies the principle of creep: a continual elongation of tissue over time with the application of a constant force.[97] A case study that compared the use of a dynamic splint with a static splint found improved ROM with the dynamic splint.[97] Such comparisons with a larger and more varied patient population may help to better understand the response of scar tissue to splinting interventions.

Duration of Splint Wear. The optimal duration of splint wear time to effectively achieve scar tissue elongation is not yet known. A conventional splinting program is a wearing schedule of 2 hours donned alternated with 2 hours doffed. Again, scientific evidence to support the therapeutic effects of this practice is lacking.[46] An animal study found that 6 hours of stress was needed to elongate scar tissue.[98] Additional investigation in humans is needed. Some reports suggest AROM during the day and splint application at night; however, this practice has not been prospectively investigated.[93]

Casting

Similar to static splinting, serial casting is a rehabilitation approach used to increase elongation of scar tissue. The application of a series of casts provides a low-force, long-duration stress that can cause a permanent, plastic deformation of connective tissue.[99] By convention, serial casting is indicated when the patient is noncompliant, does not tolerate splints, a skin graft site requires protection or immobilization, or there is persistent ROM limitation.[99–101] The use of serial casts is often advocated as a last resort treatment when a patient does not respond to traditional therapy or used in the long-term phase of recovery. Bennett et al[100] casted 35 patients with scar contractures at an average of 161 days after burn injury and found that all 35 joints had significant improvements in ROM, which raises the question of why serial casting is so often considered a last resort. Clinicians may be hesitant to apply a cast early because of open wounds. Ricks and Meagher[78] evaluated cast application immediately after skin grafting in 36 patients with lower extremity burns. They found that the cast group had significantly fewer days from grafting to wound closure, fewer ROM treatments, and no graft loss. If casting provides wound protection, maintenance of functional joint position, and permits mobility sooner after grafting, why is use of this intervention mainly considered in the long-term phase of recovery? Traditional thought processes regarding the use of serial casts with the burn patient need to be re-evaluated. Casting regimens need to be standardized including the determination of optimal frequency of reapplication, duration of cast wear, and cast material. Subsequently, studies evaluating serial casting at various stages of burn recovery may help determine their effect on wound healing, tissue lengthening, scar hypertrophy, and many other treatment outcomes. Comparative studies evaluating the effectiveness of serial casting vs splinting would also be beneficial.

Summary

Splinting and casting are accepted modalities in the treatment of patients with burn injury. However, research is needed to determine the efficacy of these modalities and the ideal regimens for their use. Well-designed, prospective studies are important to help guide therapists in their clinical decision making and foster best practice regarding the use of splints and casts in burn care.

EDEMA

The normal inflammatory response to burn injury combined with resuscitation efforts leads to the development of edema.[102–105] Edema can cause additional tissue destruction, calcification and increased bone density, delayed wound healing, compromised circulation, decreased ROM, and prevention of optimal joint position.[103,105–107] In addition, skin grafting or additional trauma can cause mechanical insufficiency of the lymphatic system. Left untreated, protein-rich edema widens the diffusion distance for oxygen and nutrients and reduces the body's defense mechanisms, leading to a high susceptibility to infections.[108] Typically, burn therapists provide interventions such as positioning devices, splints, and fluid management techniques during the emergent phase of burn care aimed at decreasing the patient's edema.[53,76,104]

Extremity Elevation

Elevation assists to decrease effusion and edema formation through the influence of gravity. By elevating an injured extremity, gravity promotes the return of fluid back to the heart via venous and lymphatic systems and decreases hydrostatic pressure by resisting flow into the elevated peripheral vessels.[108,109]

Injured extremities should be elevated at or above heart level after burn injury.[110,111] The advantage of various levels of elevation is unknown; therefore, research should be performed to determine what level of elevation is most beneficial in remediating edema. Systematically evaluating the effect of elevation on neurovascular function, pain, and tissue response in the extremities also needs additional exploration.[112–114]

Splinting and ROM

Splinting the acute deeply burned and edematous hand in the intrinsic plus position is a common practice, yet the effect of splinting on edema is unknown. Burns of the hand commonly involve the dorsal rather than the volar surface, and dorsal edema encourages wrist flexion, metacarpophalangeal joint hyperextension, and interphalangeal joint flexion.[115] A resting hand splint may help to counteract these deforming forces of edema. Conversely, precaution should be taken when splinting the massively edematous hand to watch for excessive pressure from the splint causing neuropathies or lack of active movement limiting the muscle pump. Additionally, if the hand is extremely edematous, it must not be forced into a functional position as this may lead to ischemia secondary to loss of capillary integrity. In this situation, splints should be applied with gauze wraps, rather than straps or elastic wraps.[116]

ROM exercises generally commence in the emergent phase, and both PROM and AROM have been shown to be effective to mobilize and reduce edema as previously noted.[117,118] ROM activates the muscle pump and promotes edema reduction through enhanced venous and lymphatic flow,[119] but it is unknown whether AROM is more beneficial than PROM beacuse of the benefits of active muscle pumping.

Compression and Modalities

Many therapists apply compression to the edematous limb, but the timing of compression application and the specific amount of pressure to apply is not known. Early pressure may be achieved with wound dressings. Some therapists use elastic wraps or self-adhesive compressive wrap, but using these materials in the first 72 hours to treat edema of a circumferential extremity burn is reportedly contraindicated.[107] The type of bandage (long or short stretch), tension used during application, number of layers, and condition/age of the bandage are factors that influence the quality of working vs resting pressure and compression gradient.[120]

Chronic edema can lead to tissue fibrosis and needs to be prevented.[121] Pressure garments can help to minimize edema.[122] In addition, several modalities have been used in the treatment of acute and chronic edema in burn injuries including intermittent pressure devices.[121,123] Manual edema mobilization,[124] manual lymphatic drainage,[125] and electrical stimulation[126] are also reported as effective and should be tested in the burn population.

Outcome Measures

The most common outcome measure described to determine hand edema is volumetry, which uses water displacement as a indicator of hand size.[127] Both reliability and validity are well established,[128,129] but this technique has several limitations, decreasing the feasibility of use with an acute burn patient: it is time consuming, requires specialized equipment, a consistent water temperature, a level surface, and a consistent hand position for each measurement period.[127–130] As an option, the Figure-of-Eight Method of measuring hand edema overcomes these limitations. The procedure was found to be a reliable, valid, and clinically practical tool for measuring hand edema in the burn patient and its use is recommended.[131]

Summary

Edema is generally observed after severe burns and can lead to negative consequences for the patient. Burn therapists provide interventions aimed at decreasing edema; however, many questions remain regarding exact methods, timing, and effectiveness of these interventions. Research questions specific to edema that are in need of additional investigation are outlined in Table 10.

POSITIONING

The utilization of positioning techniques is a fundamental intervention in burn rehabilitation.[15,76,92,106,110,132,133] Positioning is important to influence tissue length by limiting or inhibiting loss of ROM secondary to the development of scar tissue. Moreover, during the acute phase of burn injury, positioning is essential to aid in the reduction of edema as previously indicated, facilitate good functional alignment of compromised joints or extremities, enable optimal wound care, and prevent potential neuropathies (Table 11).[15,92,106,110,133]

Table 10. Edema research questions priorities

What is the best position to place extremities to most effectively decrease edema?
Does active range of motion assist with edema reduction? Is it more effective than passive range of motion?
Does acute edema resolve with early pressure application?
Does the provision of pressure in the emergent phase lead to a faster decrease in edema than no pressure?
If so, what is the minimum pressure required to cause a decrease in edema?
Does a combination of pressure and positioning enhance edema reduction? Does the addition of exercise to these interventions further decrease edema?
What is the most effective combination of approaches to treat edema?

Table 11. Causes of potential nerve complications among burn injury patients

Nerve	Cause/Complication
Median	Excessive stress with increased wrist flexion and/or extension
	Excessive edema formation and proliferation (especially in distal wrist and hand)
	Direct contact injury to volar aspect of wrist
	Excessive scar proliferation
Ulnar	Prolonged elbow flexion and forearm pronation (extended prone positioning)
	Excessive edema formation and proliferation (especially in distal wrist and hand)
	Entrapment due to heterotopic ossification
	Direct contact injury to volar aspect of wrist
	Excessive scar proliferation
Radial	Pressure positioning
	Excessive edema formation and proliferation (especially in distal wrist and hand)
	Entrapment caused by heterotopic ossification
	Direct injections
Hand digital	Increased pressure between fingers (compressive dressings or splinting)
	Excessive edema formation and proliferation
Brachial plexus	Prolonged side lying
	Prolonged prone pressures
	Increased traction/pressure due to splints; pressure dressings; prolonged surgical treatment
Cervical radiculopathy	Electrical injury sequelae
Suprascapular	Hyperprotraction and excessive forward rotation of the shoulder
	Prolonged pressure in supine with shoulder abduction
Long thoracic	Electrical injury sequelae
	Excessive scarring
Occipital cutaneous	Excessive pressure from head on device (donut)
Peroneal	Excessive frog lying position
	Pressure from dressings or splinting
	Excessive edema formation and proliferation
Foot digital	Hyperextension and subluxation of toes
	Increased pressure between toes from dressing or splint

Edema Management

Within the first 72 hours after burn injury, facilitating appropriate positioning is a key element in managing and potentially reversing the long-term sequelae that can arise from accumulating edema.[92,106,110,133,134] This is most evident in the upper extremities and especially in the hand where significant pooling can result in a mechanistic imbalance of intrinsic and extrinsic muscles as well as impact the bony curvature of the palmar arches. Left untreated, this situation may leave the hand significantly impaired and lead to prolonged upper extremity dysfunction and potentially permanent deformity.[106,110,128,135] Elevation is desired and careful attention should be given to the position of the wrist so that flexion does not inhibit lymphatic drainage.[92,128,134]

Total Body Applications

Positioning should be effectively applied to all compromised anatomical areas involved in a burn injury. Proper positioning is necessary in cases of large TBSA burns and situations where prolonged immobilization and tracheal intubations are necessary.[136] The traditional "model" of burn position is still relevant with the caveat that in positioning the shoulder emphasis should be placed on maintaining the "scapular plane" and thus avoiding traction on the brachial plexus (Figure 2).[93] Maintaining forearm supination as well as external rotation of the shoulder is also an important consideration. Emphasis must be placed on optimizing the balance between "anticontracture positioning" and "positioning of function" where it is paramount the therapist apply sound critical thinking and judgment that is based on maintaining position and limiting contracture potential. It is important to stress that "active positioning" be undertaken by the patient so as to facilitate recovery and the rehabilitative process.[76,90,132,135,137–139] In cases where patient compliance or patient status is not conducive to active patient participation, positioning may be achieved through the use of aids such as splints, devices, bed modifications or other types of external, rigid, or semirigid materials.[92,106,110,132–135]

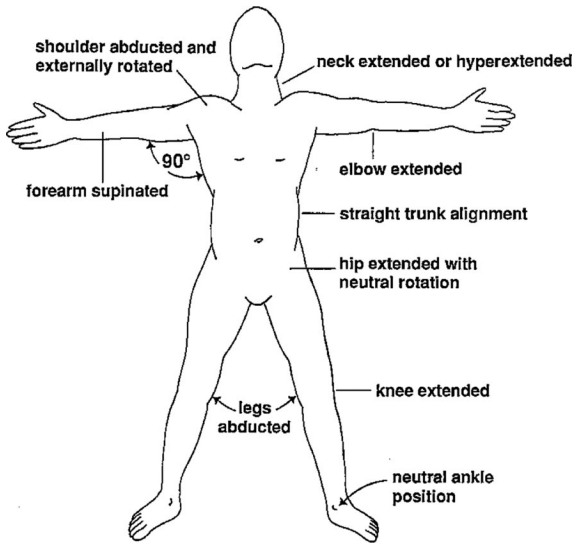

Figure 2. Standard burn positions. Reproduced with permission from *Arch Phys Med Rehabil* 1982;63:6–16.

Hand and Upper Extremity

The best position for a hand burn remains a topic of debate. General consensus supported that the length of the collateral ligaments should be preserved by placing the metacarpophalangeal in greater than 50° flexion and that the proximal interphalangeal and distal interphalangeal joints should be in a slightly flexed (~10—20°) position. It is also important to preserve and maintain the first web space and preventing complications to the carpometacarpal joint of the thumb.[92,128,134,135] Under optimal conditions, active motion of not only the hand but also the entire upper extremity is considered more important than positioning. However, when a patient is not engaged in activity, then passive functional positioning is the desired treatment approach.[132,137,139]

Position Dosage and Position Selection

Critical thinking about a patient's treatment plan is required and needs to be initiated in the early stages of burn injury.[90,106,110,133,135] Although patient survival is the primary medical goal, the role of functional and manageable positioning must be clearly defined and communicated to the entire burn team. Using this team approach is critical to ensure that the underlying consequences of poor positioning can be effectively avoided before subsequent scar contractures occur. Early discussion with the patient and family needs to clearly convey the priorities of this prescribed positioning treatment. Moreover, expectations of what long-term gains are considered functional and, therefore, achievable with the positioning devices and practices used must be defined so that patient can be an active participant throughout the entire tier of the rehabilitation process.[48,90,92,138,139] The optimal balance between positioning and AROM is not known and additional investigation is warranted to fully ascertain the best positioning treatment dosage. Additionally, prospective studies evaluating the most effective positions for specific joints and joint complexes are encouraged to achieve optimal functional outcomes.

Summary

Burn positioning is a vital construct of the burn rehabilitation specialist and is one of the first tactics used at initial evaluation. Comprehensive review and frequent assessment of the positioning protocol needs to be used over the entire course of rehabilitation to inhibit potential joint contracture and loss of function. Communication with the entire burn team as well as family and patient education is crucial to foster a collaborative, disciplined positioning prescription. Although research surrounding the approximate timing and implementation of positioning needs to be additionally evaluated, consensus is clear that positioning in burn treatment is a principle therapeutic intervention to ensure core functional rehabilitation outcomes.

BURN SCAR

The topic of burn scars in aggregate is paramount in burn rehabilitation for both patients and clinicians alike. Almost one third (32%) of responses to phase 1 of an ABA Rehabilitation Committee Delphi Study about setting research priorities were related to hypertrophic burn scar and scar management, demonstrating the high importance of this topic to burn clinicians (unpublished preliminary data).

Assessment

If the impact of therapeutic techniques on scar development and management is to be measured, reliable, valid, and clinically useful methods are needed to assess changes in hypertrophic burn scar throughout the maturation process. In 1990, Sullivan et al[140] reported the first tool that attempted to quantify scar pliability, vascularity, pigmentation, and height: the Vancouver Scar Scale (VSS). For almost 2 decades, the VSS has remained the most clinically used scar evaluation method and has been modified for various applications.[141–143] Although the VSS in its various forms is clinically practical and economical, its major disadvantage continues to be the subjectivity of the rating scale.

Several numeric scales also have been proposed to assess scar parameters, such as irregularity, pliability,

disfigurement, thickness, height, and color from a photograph.[144–146] The major limitation of these scales is the questionable validity of assessment of the three-dimensional component of scars (texture, height, and thickness) from a two-dimensional photograph. In addition, consistency in the quality and reproducibility of photographs for scar assessment is problematic.

The question as to which components of scar are clinically appropriate and most useful to study has been addressed in a survey of burn physical and occupational therapists. The scar properties considered by respondents as most important for inclusion in a burn scar outcome measure were pliability, vascularity, and height.[147] Clinically, a goal of therapy is typically to prevent, minimize, or decrease scar contracture. If a primary focus is scar extensibility, two characteristics are important: hypertrophy (which may limit pliability) and erythema (vascularity, indicating scar maturity). The VSS and numeric scales alone may not be sensitive enough to measure progress. Goniometric ROM measurements provide additional data to document changes in scar length but do not necessarily represent the scar's pliability with composite or functional movements.

The optimal scar assessment tool has yet to be designed. Accurate instrumentation is necessary to study the efficacy of scar treatment, such as the ability of pressure garments to reduce hypertrophic scar. A variety of electronic instruments for possible burn scar research application are now commercially available, some of which have been demonstrated to have an acceptable level of reliability and validity as follows.

The following scar characteristics have been measured and assessed with a variety of devices:

1. Pliability: a number of different instruments have been proposed and tested, including the durometer,[148] Torque Meter®,[149] pneumatonometer,[150] and the tonometer,[151,152] all of which use torque resistance or pressure. The Cutometer® determines skin elasticity based on suction and elongation measurement.[153,154]
2. Vascularity (erythema): several skin reflectance instruments have been used, such as the tristimulus colorimeter Chromameter.[155] The Mexameter® quantifies scar erythema (and melanin) based on the tissue's narrow wavelength light absorption.[153,154]
3. Thickness/volume: high-frequency ultrasound has been reported as a valid and reliable method for measurement of scar thickness, particularly the high-resolution DermaScan C ultrasound scanner.[153,154,156,157] Because of the expense of such instrumentation, basic research on burn scar should be relegated to burn centers and universities that can afford the equipment as suggested in Research and Education Section.

It is important to undertake correlative studies of functional extension of tissue and clinical outcomes. There is a need for a common "language" when describing scar and for effective clinical measurements of tissue, eg, ROM. When investigating scar, it is recommended to separately report single scar characteristics, eg, extensibility, as an improvement in one scar characteristic may be cancelled out by regression of another characteristic thereby ultimately indicating a static scar. When clinically accessible tools become more readily available, investigations of this type should be multicentered. However, therapists should continue to monitor scar at the clinical level by whatever methods they have available and should include aspects of patient perspective such as cosmesis and degree of itching or pain. Consensus was attained that current physical rehabilitation interventions do not affect pigmentation changes within scar.

Scar Management

The mainstay for management of hypertrophic scarring since the early 1970s has been pressure application to the involved area.[158] Discussion concluded that most centers continue to use pressure garments of various fabric types. Inserts are added as required for additional pressure. Although the exact mechanism of action is unknown, pressure seems to clinically enhance scar resolution. A recent meta-analysis demonstrated that pressure garment therapy improved scar height but not global scar score, pliability, vascularity, or pigmentation.[159] Unfortunately, the majority of studies included in the meta-analysis used subjective measures that may not be responsive to change. Mature surgical scars have also been shown to improve with pressure therapy. However, superior results were achieved when used in combination with polyurethane dressing or silicone gel sheeting.[160] The amount of pressure being provided can be measured,[161] which has facilitated research in pressure garment therapy and the use of inserts and gels.[162–165]

The earliest reports of the use of molded silicone in the management of burn scar contracture date back 40 years.[166] Since that time, various silicone sheets, gels, tapes, foam, and adhesive contact products have been introduced to burn scar management, with therapists and other clinicians establishing their personal preferences for products.[167–172] Recently, Mustoe[173] further examined the impact of silicone on epidermal signaling and has suggested that silicone contact in the epidermis aids in down regulation of collagen synthesis in the scar. Other studies indicate that

changes in the scar may be related to factors other than silicone.[174–176] Although the mechanism of action has not been fully elucidated, it seems to involve occlusion and hydration of the stratum corneum.[173] An international panel of experts concluded that there was sufficient evidence to support the use of silicone gel sheeting.[177] A more recent Cochrane systematic review confirmed that there was weak evidence for the benefit of silicone gel sheeting, but that the quality of evidence was poor.[178] Thus, more research is required on the efficacy of inserts and silicone products independent of pressure.

Scar massage is accepted as common clinical practice in burn care and is often used with patients. Despite its wide-spread use, the present literature cannot defend or dispute that massage influences burn scar. A single research article, with a small sample size, specifically addressed manual scar massage for hypertrophic burn scar and found no lasting change in scar resulting from massage.[179] Other articles in the burn literature refer to general systemic effects of massage therapy.[180] Additional effects of scar massage may include reducing hypersensitivity, itch and pain, and moisturizing and softening of the scar for the duration of that treatment session, allowing easier and greater extensibility. Additional studies controlling for type and "dosage" of massage, and using valid measurement tools for the various aspects of scar assessment described above need to be undertaken.

Summary

Hypertrophic burn scar remains a problematic challenge for burn survivors and providers. In many cases, it can severely limit a burn survivor's functional level, including work and recreational activities. Burn therapists play a key role in minimizing the impact of burn scar primarily by applying compression and other modalities directly to the scar. Methods for measuring change in scar have largely been subjective until the recent limited availability of instruments for research. Reliability and validity studies have identified acceptable devices to quantify scar pliability, erythema, and thickness. Additional research is needed to establish an optimal scar assessment tool for clinical use and to measure the efficacy of burn therapy protocols for compression, inserts, and other modalities.

PAIN/PRURITIS

Burn therapists report itch and pain to be in the top three scar characteristics important for burn patients[147] and a focus group of burn survivors confirms this finding.[181] Pain is also one of the greatest obstacles to successful burn rehabilitation. Burn pain is categorized as procedural and nonprocedural in nature and is ever changing throughout the healing and rehabilitation process.

Procedural Pain

Procedural pain is pain associated with invasive procedures, on-going burn care, and therapy.[182] Opioids are the mainstay for procedural pain management. For prolonged procedures, short-acting anesthetic agents such as nitrous oxide, ketamine, and diprivan have been recommended.[183,184] Procedural pain is usually thought to be experienced only during the acute phase of burn treatment. However, pain caused from rehabilitation treatments to elongate scar contracture also qualifies as a procedural pain and requires supplemental medication for optimal patient participation and outcome.[184]

Nonprocedural Pain

Background pain or resting pain is an underlying pain that is not influenced by activity or wound care procedures. This type of nonprocedural pain is best managed with long-acting analgesics that should be titrated to achieve an acceptable comfort level between procedures.[182]

Breakthrough pain is an episodic pain that is associated with ADL or other minor activities that require movement of injured areas. Short acting agents are best suited for breakthrough pain.[182]

Pain Management Protocols

To provide an effective pain control, the management of the three types of pain must be incorporated into an organized plan. This plan needs to be closely monitored and adjusted with respect to the patient's comfort level and stage of healing or recovery. Education of the burn center staff as well as the patient and family is essential for successful pain management.[182] Adequately addressing the treatment of burn pain from the time of patient admission prevents the development of a conditioned anxiety response.[185] Patterson et al[186] investigated the impact of inpatient burn pain on long-term adjustment and found pain to be a stronger predictor of emotional recovery than the size of the burn or length of hospitalization. The ABA Practice Guidelines for the Management of Pain suggests that the control of burn pain must begin on initiation of medical care.[182] Ongoing burn-related pain has been reported by patients several years postburn and influence an individual's work, sleep patterns, and ADL.[18]

In the past 10 to 15 years, focus has been on the development of protocols for more effective management of pain and anxiety. The Shriners Burns Hospi-

tal in Galveston has expanded their comfort protocol for children to include guidelines for the treatment of anxiety, acute stress disorder/posttraumatic stress disorder, itch, and pain related to rehabilitation.[184]

Anxiolytics

High levels of anticipatory procedural anxiety can influence the effectiveness of opioids in the treatment of burn pain. The addition of antianxiety medications as an adjunct to opioids has been shown to reduce background and procedural pain.[18,182,184,187,188]

Alternative Methods: Nonpharmacologic Management

Hypnosis. The hypnotic technique of rapid induction analgesia has been reported to reduce baseline pain levels as well as having an impact on pain perception, anticipatory anxiety, and level of relaxation before and after burn care.[189,190] Patterson et al[191] suggested that hypnotherapy is more appropriate for high-intensity, limited duration pain associated with dressing changes, wound debridement, and joint ROM. The continued use of hypnosis through hospitalization may also prove to be useful for on-going pain management related to rehabilitation as patients are weaned from opioids.[192]

Distraction Techniques. The use of nonpharmacologic methods to treat burn pain and anxiety by refocusing attention away from the pain has been reported.[189] Distracting activities are effective with younger children, whereas music, art therapy, and relaxation techniques are effective with adolescents.[185] Commercially available interactive video games have been used during therapy with children and adults to distract patients from painful procedures while encouraging active limb movement. This and other forms of distractions should be studied further to determine their impact on rehabilitation goals.[193]

Virtual Reality. Virtual reality has been demonstrated to be beneficial for reducing pain and anxiety in patients with burns as perceived time spent in painful activities is shorter.[185] Virtual reality allows the patient to be immersed in an alternate reality instead of focusing on the procedure and pain.[194] Additional study is indicated to investigate out-patient usage during rehabilitation and use in combination with anxiolytics.[187,194–196]

Music Therapy. Studies examining the effects of music therapy suggest that anxiety and the fear of painful procedures as well as the patient's perception of pain can be positively influenced by music.[197–200]

Massage Therapy. Research has demonstrated a significant decrease in baseline pain when a 20-min massage was performed before wound care.[201] Massage was found to be a beneficial adjunct for chronic pain in adults and children.[187,201]

Trancutaneous Electric Nerve Stimulation. The application of trancutaneous electric nerve stimulation (TENS) has been reported with some measure of success.[202–205] Despite this research support, TENS does not seem to be broadly applied in burn care as an adjunctive pain modality. Since there are some positive results related to the application of this modality, it would be worth specifically investigating its use in cases where other adjunctive care is unsuccessful or directed at managing predictable pain related to specific care procedures.

Pruritis

Pruritis remains one of the most poorly understood and managed aspects of burn care. Moisturizing creams and oral antihistamines are commonly used but may provide only partial or temporary relief. Lotions containing colloidal oatmeal have been found to be more effective than other formulations.[206]

There is also some evidence to suggest that TENS might positively influence the complaints of itch that are prevalent after burn wound closure.[207,208] It would be helpful to explore further if the application of this modality would aid patients to manage their pruritis on an ongoing rather than short-term basis. Additional investigations are needed to determine the efficacy of TENS compared with pharmacologic management of itch.

Summary

Pain experienced by patients with burn injuries interferes greatly with rehabilitation interventions (Table 12). Although it is beyond the scope of practice for occupational and physical theraphists to prescribe or administer pain medication, it is important for burn therapists to understand pain medication categories and their effects to advocate for better therapy-related procedural pain control. Several nonpharmacologic pain interventions are available and should be considered and tested by burn rehabilitation personnel along with other research areas as well (Table 13).

Table 12. Areas of consensus

Optimal pain management should begin on the day of admission
A dedicated pain management team is needed to establish effective treatment protocols for the management of pain throughout all stages of recovery
Optimal pain management enables greater patient participation and compliance in rehabilitation

Table 13. Future research directions

Investigate further the relationship of pain and pruritis in burn scars
Further investigation of alternative/nonpharmacologic measures to treat pain and anxiety
Determine the influence of pressure treatment on pruritis
Investigate the role of pruritis in burn scar assessment
Further evaluation of scar hydration and its effect on pain and pruritis
Evaluation of the relationship between scar maturation and pruritis
Research improvement of pain management during therapy-related procedures

PHYSICAL AGENTS TO MANAGE BURN SCAR

Modalities have been historically used in rehabilitation for the relief of pain, to enhance healing, and to improve movement. Modalities commonly associated with rehabilitation are those that use temperature, sound or mechanical waves, light, and electricity. Application of heat and the use of electrotherapeutic agents have been described in the burn literature.[209] The rationale for the use of modalities in burn rehabilitation is similar to that for the general use of physical agents. The treatment rationale include increasing local circulation, increasing extensibility of scar tissue and relaxation of muscle to improve mobility, increasing hydration of the scar tissue, encouraging desensitization of the scar, and decreasing pain.

Application of thermotherapeutic and electrotherapeutic modalities in burn care is best categorized in functional terms rather than by specific modality. Examples of functional terms related to the modalities include decreased stiffness of collagen tissue (scar) and decreased pain for thermotherapeutic devices, whereas those related to electrotherapy approaches include wound repair, functional muscle stimulation, and pain control.

Therapeutic Heat

Data exist that reflect the following effects of therapeutic heat: increased blood flow,[210,211] decreased stiffness of scar tissue,[212–216] decreased pain,[217,218] and decreased muscle spasm.[219,220] Placebo effects are also reported in the literature.[221,222] Specific publications and clinical perspective related to the use of certain thermal physical agents in burn care or the treatment of scar are as follows.

Decreased Stiffness of Scar Tissue. The physics of ultrasound and its reported effects on scar tissue suggest this modality's indication for the treatment of scar. The density of scar tissue should make it a target for ultrasound energy.[223,224] Passive elongation of scar tissue, which is a common technique in burn rehabilitation, combined with ultrasound may facilitate increased tissue length.[213,216] The use of ultrasound was reported in treating burn scar with limited success.[225] However, the parameters, particularly sound wave frequency used, were limitations of the study. Parameters that direct more of the ultrasound energy to more superficial scar and the settings of the duration and intensity of the energy are indicated for investigation.

It has been reported that a combination of the application of paraffin and scar tissue elongation can be helpful in increasing ROM.[226,227] Proposed reasons of this modality might be beneficial include the heating of the scar and also the moisturizing of scar by the mineral oil included in the standard paraffin mixture. There may also be a hydration effect that could enhance extensibility of collagen tissue.

Additionally, other thermal modalities such as hot packs and fluidotherapy may be beneficial via their application of heat to the scar or to decrease tactile sensitivity but these modalities have not been evaluated in the burn population. Based on available data, it is recommended that superficial heat interventions be investigated additionally as to their potential benefits to treat contracture and stiffness associated with burn scar.

Pain Control. No reports specifically support the use of thermal agents in the control of pain or pruritus in patients with burns and burn scars.[227] However, pain was often not a variable that was measured well in terms of actual pain control vs procedural pain. Given that there is a general clinical consensus that these physical agents might reduce pain through a variety of mechanisms, it could be useful to purposely study the effect of heat, particularly on procedural pain during rehabilitative interventions in patients with burns. In addition, the differences in wet and dry heat should be additionally explored.

Decreasing Muscle Spasm. Superficial heating modalities might also play a role in relaxing muscle and, thereby, allowing for increased patient mobility secondary to decreased patient anxiety or muscle tension. No data exist in relation to this application in burn care.

Electrotherapy

General data exist that support the use of electrotherapy for wound healing and tissue repair,[228,229] functional muscle stimulation,[230] and pain control.[231–233] Applications of electricity in terms of iontophoresis in the management of various scarring has also been

reported.[234–236] The literature reports the following applications of electrotherapy in burn care.

Wound Healing. A variety of electrical applications have shown some merit in healing either burn wounds or donor sites.[237–239] These data have not led to a change in the standard of care for either injury. It would be of particular interest to investigate the use of electrical stimulation in the healing of wounds from chronic scar breakdown that sometimes occur during the remolding phase of scar healing.

Functional Muscle Stimulation. One report exists on the use of functional electrical stimulation (also referred to as neuromuscular electrical stimulation) that was applied in a case series for the purpose of addressing apparent muscle tightness or muscle imbalance in burned hands of three patients.[240] Additional research is needed to determine the efficacy of this modality in facilitating functional restoration and minimizing impairments related to soft tissue tightness or muscle weakness in the burn population.

Iontophoresis. There are a few reports of the application of iontophoresis to deliver medication intended to treat burn scar.[236,241] The articles do not provide sufficient evidence to warrant broad application of this modality to the care of burn scar; however, preliminary results are intriguing and should serve as a catalyst for additional investigation of this intervention. Investigation should scrutinize products that can be delivered via this electrical potential mechanism, including dose response of intensity and duration of the stimulation and concentration of the deliverable product.

Summary

Data demonstrate potential favorable effects of a variety of thermotherapy and electrotherapeutic modalities on many physical issues patients and therapists must manage during burn rehabilitation. Human clinical trials are needed to establish the utility of any of these interventions as positive adjuncts to the management of burn scar.

OUTCOMES OF BURN SURVIVORS

Patient outcomes and outcome measures are distinctly different. A patient outcome is a result, whereas outcome measures refer to how the result is quantified. As survival from large burns has become more common, mortality is no longer a predominant outcome measure. More recently, an emphasis on rehabilitation and outcomes has occurred as measured in terms of physical and psychological function, the ability to complete daily tasks and quality of life.[242] Measuring burn survivors' physical functioning abilities after rehabilitation is important on many levels: to determine efficacy of therapy interventions, establish evidence-based "best practice" standards of care, predict long-term disposition of patients, compare burn survivors with other patient populations, and potentially reduce the cost of care by identifying the most effective treatment.

Specific tests and measures used in outcome studies are varied and include the following: ROM and strength measurements,[64,243,244] cardiovascular function,[9,10,68] Jebsen-Taylor Hand Function Test,[244,245] return to work[246] or school,[247] Functional Independence Measure,[248,249] ADLs,[64,250,251] Michigan Hand Questionnaire,[243,244] Disabilities of the Arm, Shoulder, and Hand,[47,252] AMA Guides to the Evaluation of Permanent Impairment, fifth edition,[253] Burn Specific Health Scale,[254,255] and the ABA/Shriners Hospitals for Children Burn Outcomes Questionnaire.[256]

Model/Conceptual Framework

In 2001, the World Health Organization published the International Classification of Functioning, Disability, and Health (ICF).[257] This classification was developed as a method to evaluate the effectiveness of health care processes. The ICF model provides a framework for consideration to look at burn rehabilitation outcomes.

Outcome studies of burn survivors frequently have used the ICF dimensions of body function and activities.[258] In addition to these outcomes, assessment of a person's level of participation in daily life (eg, domestic life roles, employment/education roles, interpersonal interactions, and community, social and civic life) provides insight into their quality of life, well being, and health. However, these metrics may lack adequate sensitivity to change in physical impairments and functional limitations in the acute stage of burn rehabilitation.

It is recommended that a comprehensive outcome tool or group of tools be developed that measure body function and structure (eg, ROM, strength, sensation, pain, edema, amputation, and scar), functional activities, and quality of life based on a person's subjective experience of participation in daily life.

Choosing Outcome Measures

There are few "prescribed" assessments or outcome measures specifically for patients with burn injuries. Therapists commonly use clinical data (ie, ROM measurements, grip and pinch tests, sensory and coordination tests, ADL evaluations, and scar evaluations) for the early stages of rehabilitation.

Desirable characteristics for outcome measures include the following: relating to a conceptual frame-

work, availability of norms, ease of administration, acceptability from a patient perspective, reliability, validity, and responsiveness to change.[259] Developing a burn-specific outcome measure would require many years of testing to generate the characteristics listed above. There are many outcome measures in existence that are used in other areas of rehabilitation. Simons et al[48] compiled an excellent reference list of assessments. One advantage of choosing assessments that are used in other rehabilitation populations is that burn therapists would be able to compare results.

Authorities in burn rehabilitation should determine the components of a minimal data set for each stage of rehabilitation. The final recommended tool would be a battery of outcome measures in all domains: impairments, activity, participation, and quality of life.[260] Multicenter testing of these instruments for validity and responsiveness to change in the burn population is recommended as the next step to additionally refine the data set.

Clinical impairment data does not always correlate with functional outcome.[47,261] However, in a study that examined burn survivors with hand burns, the correlation between impairment and disability was shown to be moderate.[47] Additional investigation to establish correlations between impairment and disability in other burn survivor populations is required.

Summary

Burn therapists are primarily responsible for the physical rehabilitation of patients with burn injuries. Therefore, they need to be involved in choosing the measures used in evaluating the outcomes of rehabilitation. Because therapy impacts all aspects of a person's ability to return to a fulfilling life, outcome assessments should include body function/structure, functional activity, and participation. Patient-reported quality of life outcomes are vital to understand the impact of our rehabilitation efforts. Determining which outcome measures to use in research is the first step in comparing the effectiveness of various treatments so that the function and quality of life of burn survivors can be improved.

HEAD AND NECK BURNS

The face and neck regions of the body present with many challenges due to the unique characteristics of these areas. The contours of the face and mobility of the neck along with the presence of free skin edges of facial apertures such as the eyelids or lips make it an anatomically difficult area to manage with conventional treatment techniques.

Standardized Facial/Neck Evaluation

The lack of a single objective evaluation method that is universally accepted to evaluate severity of contractures for the face and neck compounds the above noted problems.[262] Many methods have been cited as objective measurement techniques for the neck,[263–268] mouth,[269–274] and eyes.[262] However, no consensus exists on universally accepted methods of assessment. A standardized evaluation of the face and neck needs to be established to evaluate the effectiveness of treatment techniques on contractures of this unique region. To help identify an optimal standardized evaluation, additional studies are needed to assess current measurement techniques used for the face and neck.

Current Rehabilitation

A multitude of splints and compressive devices have been described in the literature to assist with minimizing scar contracture or scar hypertrophy of the face and neck. Most devices described for controlling microstomia are designed to apply stress to tissue around the mouth.[96] Serghiou et al[275] found that 84% of burn therapists surveyed initiate microstomia devices after 72 hours post burn. In contrast, Heinle et al[276] reported the initiation of a microstomia device 25 days postinjury supporting the need for clinical agreement. To provide optimal scar contracture prevention, more of an emphasis should be placed on evaluating the effectiveness of positioning devices in the acute wound healing stage that include intraoral devices.[277] Additionally, several different methods and modifications to splint the neck have been described with varying outcomes.[18,136]

There are no comparative studies evaluating the effectiveness of splinting or compressive devices.[275] Laser Doppler imaging may be a useful technique to determine adequate compression for the face and neck.[278] Thus, future studies should include an objective comparison of the interventions and not be limited to the description of a given device.

Improved Face Mask Fabrication

Transparent face masks made of hard thermoplastic material are commonly used for the prevention and treatment of facial scarring.[18] No significant difference was found between the pressure exerted under a rigid face mask compared with a custom fabric garment with underlying silicone.[279] However, Allely et al[278] found that a silicone-lined facemask demonstrated increased contact and decreased blood flow as compared with a conventional, nonsilicone facemask. Precise techniques and materials need to be developed to reduce secondary adjustments caused by an

inaccurate initial fitting.[280] An emphasis must be placed on comparing different fabrication procedures including computer-assisted design and products to help determine a standard of care. Once these optimal methods are established, efforts should be made to improve technical skill during face mask fabrication.

Implications of Facial Exercises

Facial exercises are commonly recommended to decrease the effects of burn scar contracture during the course of burn rehabilitation. However, 84% of clinicians do not prescribe facial exercises during the first 72 hours postburn,[275] whereas 92.6% surveyed initiated facial massage and mouth stretching during the long-term rehabilitative phase.[275] This finding supports the notion that more emphasis should be placed on prolonged stress of the involved tissue vs AROM of the affected area. A literature search found no studies that investigated the effect of active facial exercises on facial burn scar contractures. A practice called into question is the benefit of commonly suggested active facial exercises and their role in preventing the development of burn scar contractures. There is limited evidence that suggests that exercises of specific facial muscles may prevent atrophy and, therefore, preserve natural contours of the face.[281] However, these results need to be validated and additional research performed to identify exercise programs that both preserve natural facial contours and provide maximal tissue length adaptations.

Image Enhancement Techniques

Facial burns can lead to significant cosmetic and psychosocial implications.[275] Teaching burn survivors with an altered facial appearance how to communicate positively and encouraging acceptance of their altered appearance are important aspects of burn rehabilitation. Image enhancement techniques and behavioral skills training should be incorporated into the prescribed rehabilitation program after a facial burn.[282]

Summary

Rehabilitation after burns to the face and neck region can be difficult to treat and treatment interventions are highly variable. Studies are needed to identify standardized evaluation components for the face and neck. Comparative studies are also needed to help identify effective splinting and compression interventions to address facial and neck contractures and scar hypertrophy. The implications of commonly prescribed facial exercises warrant additional investigation to ascertain programs that preserve natural facial contours and provide maximal tissue lengthening. Teaching burn survivors how to communicate positively and encouraging acceptance of their altered appearance are important components of burn rehabilitation.

CRITICAL CARE ASPECTS

Patients with extensive burns can present with challenging complications as a result of their injuries. Prevention and management of these critical problems remain debatable and in need of research to define best treatment approaches.

Amputations Related to Burn Injury

Amputations resulting from burn injuries can be unique in terms of their rehabilitative management due to compromised skin integrity of a residual limb. Open wounds, fresh skin grafts, pain, and scar contractures that limit movement of a joint may prolong and complicate the rehabilitation of a burn patient with an amputation.[76,283–286] Literature is scarce regarding the rehabilitative management of burn injury-related amputations. Rehabilitation focuses on preprosthetic and prosthetic training that are geared toward functional independence with ADL.[76,283,286–289] One study compared patients with skin grafts on lower extremity residual limbs with patients without skin grafts and found that the presence of skin grafts does not seem to limit a patient's ability to achieve independence with ambulation or put them at greater risk for complications.[290] Malone et al[291] and Folsom et al[292] described the benefits of early prosthetic fit and rapid entry into rehabilitation. To date, however, the optimal timing of prosthetic fitting and course of rehabilitation has not been investigated in the burn population. Some reports indicate that early fitting of a prosthetic device may positively affect a patient's functional independence and long-term utilization of the prosthesis.[287,293] Pylons and other temporary devices are introduced to assist with ambulation and upper extremity function. The timing of pylon use and training and by-pass prosthetics depend on each facility's guidelines.[284,286,288,289] Currently, the practice of early vs late prosthetic fitting varies among burn centers and it is primarily dependent on physician practice. In general, prosthetics are introduced when all grafting and other surgical procedures of the site have been completed. Today, prosthetic technology has advanced significantly and offers a wide variety of options and choices to amputees and rehabilitation professionals alike. Conventional and myoelectric prosthetic components have become smaller in size and more compact allowing for longer length residual limbs that provide for more efficient lever and prosthetic fit. The literature describes various techniques of surgically managing burn-related amputations; however, addi-

tional research is needed to determine the relationship between the surgical management of burn injury-related amputations and prosthetic utilization.[294] Additional investigation is needed to examine prosthetic utilization as it relates to early vs late prosthetic fit, appropriate prosthetic options for burn amputees, and the treatment of pain and hypersensitivity that complicate the rehabilitation of burn survivor amputees.[18]

Heterotopic Ossification

The etiology of heterotopic ossification (HO) remains unknown; however, possible predisposing factors may include localized trauma, hemorrhage resulting from repeated localized minor trauma, prolonged immobilization of extremities, forcible movement of joints, infections, smoke inhalation, and tissue hypoxia.[295–299] Klein et al[297] reported that there is a strong relationship between wounds around the elbow of patients that remain open for a period of time and the development of HO. HO symptoms include pain around a joint, decreased ROM, joint stiffness, localized swelling and tenderness, and increased temperature.[296,299] The diagnosis of HO is made based on clinical symptoms and through x-rays, bone scans, ultrasonography, CT, and magnetic resonance imaging. The timing and the most accurate diagnostic instrument should be additionally investigated.[299–301] Surgical intervention to resect heterotopic bone is usually delayed until the active process of HO development has subsided; the HO has bridged the affected joint or if the HO has encased a nerve severely affecting the function of the patient.[296,297,300–302] Because of its unknown etiology, it is difficult to prevent and treat HO.[297,301] The approach of physical rehabilitation following the development of HO is controversial. Suggested rehabilitation programs after HO include active and active assistive ROM programs that incorporate splinting and positioning within the pain tolerance of patients[18,295,298,303] and PROM and stretching programs.[298,304] It has been recommended that postoperative ROM is initiated between days 2 and 7 in the form of active or PROM.[300] The use of continuous passive motion soon after HO surgery may help decrease pain and may be an adjunct in gaining ROM; however, the use of continuous passive motion in the management of HO should be examined further.[301] Future clinical trials should focus on evaluating the effectiveness of current occupational and physical therapy treatment regimens in managing the sequelae of HO and investigate whether there is a possible correlation between skin contracture and HO.[18]

Neuropathy

Patients with burn injuries, who are diagnosed with peripheral neuropathies, present with symptoms of numbness, tingling, decreased hearing, weakness in their distal extremities, sensory loss, decreased endurance, and decreased ROM.[305,306] There is a great discrepancy regarding the incidence of peripheral neuropathy that is attributed to the methodology of documented studies.[307] Studies conducted by Helm et al[305] and Marquez et al[308] suggest that there is a correlation between neuropathies and burn injury, the depth of the burn injury, length of hospitalization, and complications of the injury. In addition, Kowalski et al[307] reported that factors leading to mononeuropathies may include electrical injury, history of alcohol abuse, and the number of days in the intensive care unit. Early identification of neuropathies, in combination with intensive treatment (ROM and splinting) may help to prevent deformity.[309] Factors that may contribute to neurological damage and the development of a neuropathy may include nerve damage during escharotomies or fasciotomies and deep debridement, inappropriately performed intramuscular injections, prolonged edema, inappropriate positioning, tight dressings over superficial nerves, incorrect splinting, and aggressive exercise programs and medication.[305,308] Even though neuropathies are difficult to assess during the acute stage of a burn injury, ongoing comprehensive physical examination accompanied by electrophysiologic testing at regular intervals may help identify neuropathies early in the treatment of patients and positively affect functional outcomes.[307,310,311] Preventatively, physical rehabilitation should focus on appropriate positioning/repositioning and splinting, avoiding high-pressure wraps, practice edema reduction techniques, and avoiding aggressive exercise programs.[305,307,308] Additional studies are needed to develop a better understanding of the risk factors that contribute to the development of neuropathies. Such studies would develop prevention programs and define the role of physical rehabilitation in the treatment of neuropathies.[18,310] Additional investigation is required to determine the appropriate timing and frequency of nerve conduction studies postburn in an effort to better detect and treat neuropathies. Future studies may also answer whether there is a neuropathic correlation with the patients' catabolic state-related atrophy or disuse atrophy. Physical rehabilitation professionals should study rehabilitation interventions related to neuropathies prospectively to determine if they resolve or if they result in contractures to better guide the practice of therapists.

Ambulation of the Ventilated Patient

Rehabilitation professionals should be more attentive in getting ventilated patients out of bed, sitting in a chair, or ambulating when their medical status allows to prevent complications such as pneumonia and pressure ulcers.[312,313] Assisted mechanical ventilation alone should not be the deciding factor that keeps a patient in bed. A patient's status should be assessed by the entire burn team and recommendations should be made as to whether the patient can sit up in a chair or ambulate. Consensus was found that patients with burns should be mobilized as soon as possible, irrespective of their ventilatory status, as long as they have been assessed by the burn team and no contraindications against mobilization exist.

Summary

Critical clinical problems that are out of the ordinary create dilemmas for the clinician. Part of the reason for uncertainity in care is because each condition is relatively uncommon so clinical experience is limited. These conditions need to be studied in a prospective manner preferably by the way of multicenter research.

CONCLUSION

Burn rehabilitation is a patient care service important to the recovery and ultimate outcome of burn survivors. Although the overall benefits of burn rehabilitation are not questioned, the specifics of the practice need much more investigation and development. Current status and topics in the need of clinical advancement in burn rehabilitation have been addressed by the way of literature reviews and consensus report from a Burn Rehabilitation Summit. Possibilities for future and sustained Summit meetings are being explored. In the meantime, clinicians can use this information to compare their professional practices with areas of concern presented by the authors who are cross-representatives of burn rehabilitation personnel. Individuals interested in these subject areas can use the information as a starting point to initiate research projects perceived as needing investigation. Multicenter research initiatives are highly encouraged.

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